

# Effect of forage inclusion in diets on milk yield and milk components of dairy crossbreed ewes managed on an accelerated lambing system

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## Introduction

Sheep dairies produce 1.4% of the global milk for human consumption. Sheep milk is rarely consumed as fluid milk. Instead, it is mostly processed into cheeses, whey cheeses and yogurt (Bencini, 2002). Dairy sheep production is heavily concentrated in the Mediterranean, with France, Greece, and Italy, as well as Romania, being leading producers (Balthazar et al., 2017).

Sheep flocks are managed to lamb and start lactating within a short period of time between early fall and late spring in Europe (Sitzia et al., 2015) and mostly in early spring in the United States (Jaeggi et al., 2005), with one annual lactation (~160 days) (Table 1). Most sheep milk is seasonally available. While seasonal production systems are warranted in mountainous regions and Mediterranean Europe, sustainable sheep milk production in the US Northeast – with abundant forage and achievable cost-effective production of high-quality winter feed – is important for economical farm viability.

Table 1. Milk production of relevant breeds in the US and North America.

Item	Breed				
	East Friesian	Lacaune	Finnsheep	Dorset	Finnsheep × Dorset
Reference	(Thomas, 2014)	(Thomas, 2014)	(Sakul and Boylan, 1992)	(Sakul and Boylan, 1992)	(Kochendoerfer and Thonney, 2018)
Region	US	US	North America	North America	Cornell sheep flock
Lactation yield, kg	209.4	194.8	66.0	72.0	176.3 <sup>a</sup>
Lactation days	161	155	~120 <sup>2</sup>	~120 <sup>b</sup>	122 <sup>a</sup>
Fat, %	5.8	6.3	6.0	6.5	6.3
Protein, %	4.8	5.2	5.4	6.1	5.3
Lactose, %			4.7	4.8	4.8
Milk solids, %			16.8	18.2	

<sup>a</sup>1.45 kg/day on average with 73 days lactation length, 1.67 times per year.

<sup>b</sup>Milking started in late April or early May and lasted until the first week of September.

Between 2016 and 2018, a flock of 46 meat-breed Finnsheep × Dorset cross ewes were milked on the STAR-accelerated lambing system to achieve year-round sheep milk production. With 1.67 lambings per year, the ewes achieved 176.3 kg of milk per year. Litter size and conception rates were very high with 3.5 lambs per ewe sold or retained as replacements per year and 87% conception rates across the 9 breeding seasons of the 2-year experiment. Aseasonally polyestrous meat sheep breeds can be utilized for milk production in accelerated lambing systems in short (73-day) lactations and can be managed for meat and milk production with year-round product availability.

However, farmer and stakeholder commentary from the US Northeastern sheep dairying community suggested that 5 lambing periods per year are too labor intensive to be manageable in a small-scale, on-farm, setting. Additionally, the pelleted research diet did not reflect actual Northeastern sheep dairy diets due to low forage inclusion (300 g hay per head per day).

A feeding and milking trial was designed to test the following hypotheses: 1) Crossbreeding with East Friesian dairy sheep genetics will achieve extended lactation persistency to 120 days and thus allow for a step down in lambing intensity from the STAR accelerated lambing system, 2) Crossbreeding will retain out-of-season breeding ability of the hybrid ewes and achieve an accelerated lambing system with 1.5 lambings per ewe per year and 3 lambing periods per year, and 3) Higher forage inclusion will negatively affect milk yield.

## Methods

In February 2019, 23 Finnsheep × Dorset ×  $\frac{1}{4}$  East Friesian first parity ewes that were 11 to 12 months of age at lambing, were randomly assigned to 1 of 2 pens within 2 dietary groups, HF (High Forage) and LF (Low Forage). Both groups were offered the same completely balanced, pelleted concentrate diet ad libitum plus hay (Table 2). The HF group was offered hay ad libitum, while hay intake was restricted for the LF group. These diets were fed for about 10 days prior to lambing. Lambs were removed 12 hours after birth and reared artificially on cold milk offered ad libitum. After removal of the lambs, the dams were milked in a low-line, 6-stanchion parlor, at the Cornell University Teaching Barn twice daily at 7 am and 5 pm. Feed intake (pen values) was recorded daily. Milk yield and samples for NIRS component analysis (Woolpert, 2017) were collected from each ewe once per week. Ewes and lambs were weighed weekly. Blood samples for metabolite analyses were collected prepartum, and on days 1, 7, and 40 of lactation. Feed and fecal samples were collected for digestibility analysis (Thonney, 1979).

Quadratic equations were fitted to milk protein and fat yield as well as component concentrations. An exponential equation was fitted to the milk yield data [1]. Total lactation yield was calculated by integrating this equation [2], peak yield [3] and day of peak [4] were calculated using the first derivative of the equation (Wood, 1967):

$$\begin{aligned}
[1] \quad & Y = ax^b \exp(-cx) \\
[2] \quad & Y = \frac{a}{c^{b+1}} \Gamma(b+1) \\
[3] \quad & Y_{(max)} = a \left(\frac{b}{c}\right)^b \exp(-b) \\
[4] \quad & X = \frac{b}{c}
\end{aligned}$$

The lactation yield and component curve parameters were analyzed statistically for effect of diet with a linear model including fixed effects of diet and pen within diet and with maximum days in milk as continuous covariate using *lm* in R (R-Core-Team, 2019).

Table 2. Composition of experimental diets (% of DM).

Ingredient	35% pfNDF <sup>a</sup>	2 <sup>nd</sup> cutting hay
Soy hulls	42.4	
Wheat midds	20.1	
Corn	24.1	
Soybean meal	8.6	
Molasses	1.7	
Cornell sheep premix	1.06	
Ammonium chloride	0.78	
Calcium carbonate	1.12	
Pellet binder	0.26	
<i>Measured components</i>		
DM (% of feed)	89.5	90.9
DDM (Dairy One estimated TDN)	80.6	59.0
CP	17.0	14.2
NDF	41.1	54.4
pfNDF	35.1	26.4
INDF	6.0	28.0
NSCHO	34.0	24.4
EE	2.6	5.0
Ash	5.3	5.0

<sup>a</sup>Pelleted diet, offered ad libitum to both groups.

Serum NEFA concentrations were determined enzymatically [ELISA] using the HR series NEFA-HR (2) Wako kit (Wako Life Sciences, Inc. Mountain View, CA) according to the manufacturer's instructions. Samples were plated and run in triplicate. The data were analyzed as a mixed linear model with the *lme4* package in R (Bates et al., 2015) with effects of diet, pen within diet, ewe as a random variable, and the 4 sampling timepoints and their interactions with diet as fixed effects.

Feed intake data are expressed as raw means in percentages of body weight.

## Results and Discussion

Ewes in both groups consumed on average 3.1 kg DM per day, with ewes in the LF group consuming 2.73 kg DM of the concentrate diet and 0.37 kg hay, and the HF group consuming less concentrate (2.60 kg) and more hay (0.50 kg) daily. With average body weights of 72.6 kg for the HF group and 70.8 kg for the LF group, the ewes consumed 4.3% and 4.4% of their BW, respectively. Thus, feed intake was high with lower forage inclusion resulting in slightly higher feed intake.

The estimates of the lactation curve parameters a, b, and c were slightly different but not statistically different between the two forage inclusion levels (Table 3). Daily milk yield and total lactation yield were higher ( $p < 0.04$ ) for the LF diet group. Peak lactation was substantially higher ( $p = 0.011$ ) in the LF group, with peaks occurring earlier than for the HF group. Milk protein and fat percentages were higher for the HF group, but protein and fat lactation yield overall was higher for the LF dietary treatment. This reflects the differences between forage levels in milk yield (Table 3)**Error! Reference source not found..**

Table 3. Statistical analysis.

	Diet		SEM	p-value
	HF	LF		
a	2.29	2.21	0.329	ns
b	-0.02	0.10	0.085	ns
c	0.004	0.009	0.0026	ns
Daily milk yield, kg	1.55	1.96	0.134	0.042
Total lactation yield, kg	166	213	14.3	0.033
DIM <sub>(max)</sub>	110	105		
Peak yield, kg	1.67	2.70	0.245	0.011
Day of peak	27	16	5.07	ns
Protein %	5.6	5.0	0.83	ns
Total milk protein yield, kg	8.6	9.3	0.86	ns
Fat %	6.1	5.3	0.84	ns
Total milk fat yield, kg	9.4	10.3	0.68	ns

The raw milk yields are plotted in Figure 1 together with the average of fitted lactation curves for the HF and LF levels. Reflected by the variation in milk production among ewes, none of the ewes had been selected previously for milk production. Due to the small size of the Cornell sheep flock and the even smaller size of the East Friesian crossbreed dairy flock, selecting for milk production through culling low producing animals has not yet been an option. Additionally, literature investigating Italian Sarda ewes suggested that high variation is common in ewe milk production (Cappio-Borlino et al., 1995). Further investigation into the shape of lactation curves for meat × dairy crossbreed ewes is necessary to find the best ways to describe lactation curves capturing the high early peak yields often found for traditionally meat breed ewes (Reynolds and Brown, 1991). Future breeding and selection for milk production will achieve higher lactation yields.

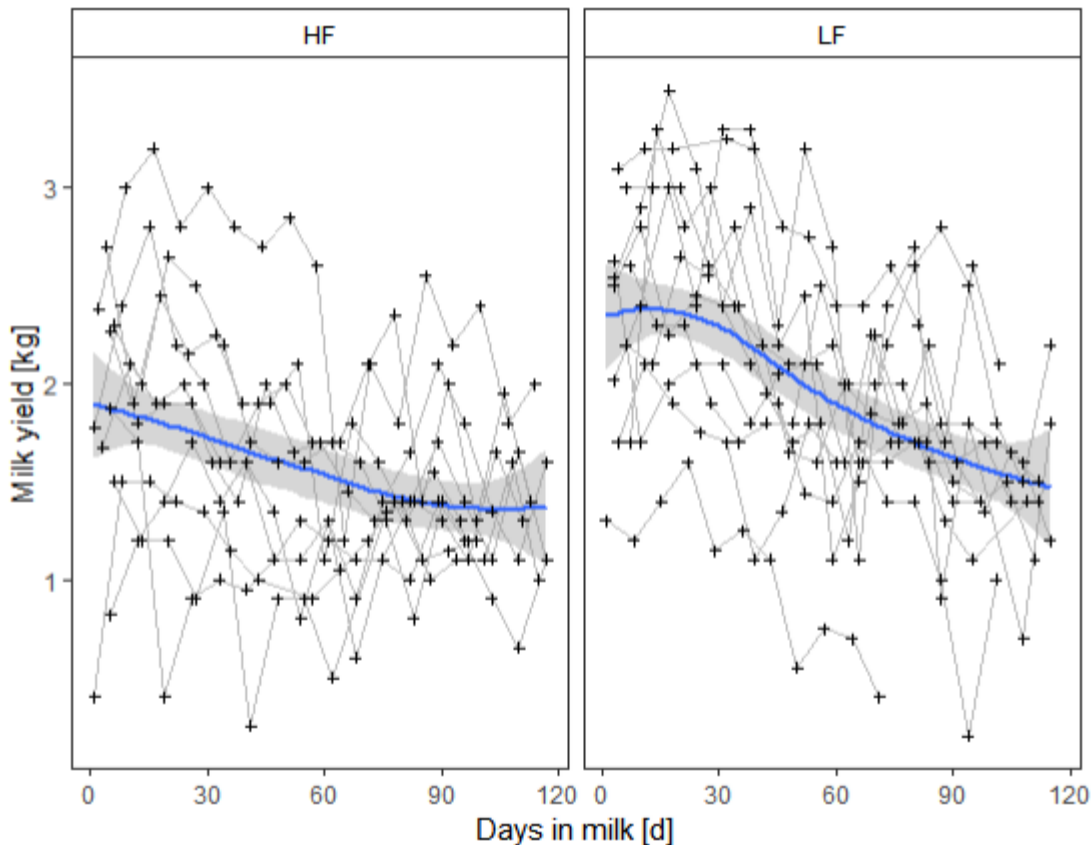


Figure 1. Lactation curves for HF dietary treatment (left) and LF dietary treatment (right). Raw data plotted with regression line and 95% CI.

Litter size differences between dietary groups were small, with 1.3 and 1.5 lambs born for the HF and LF groups, respectively. There was no effect of litter size on milk yield. The literature suggests smaller litter sizes for US East Friesian dairy sheep (Thomas, 2014) than for Finnsheep × Dorset cross breeds (Kochendoerfer and Thonney, 2018). The lower litter sizes for ewes in this experiment may be due to ewes being in their first parity.

There was no effect of dietary forage level on serum NEFA levels of ewes in early lactation. Differences in digestible nutrient intake between the diets may not have been large enough to affect serum NEFA concentrations. Overall, the serum NEFA concentrations were very low ( $< 300 \mu\text{eq/L}$ ), indicating that ewes were in positive nutrient balance and were not mobilizing adipose tissue reserves.

With ewes being re-bred on day 97 of their lactation utilizing teaser rams between 17 and 10 days prior to breeding and CIDRs between 7 and 0 days prior to breeding (Inskeep, 2011) and with a conception rate of 82%, we can conclude that the out-of-season breeding ability of the Finnsheep × Dorset crossbred ewes was retained in our  $\frac{1}{4}$  East Friesian yearlings.

## Summary

Similar to our previous milking experiment utilizing aseasonally polyestrous meat breeds, this experiment was successful in achieving high milk yields. With a total lactation yield of 213 kg for the LF group in 105 days of lactation, milk yields were higher than previously reported lactation yields for East Friesian dairy ewes (Thomas, 2014). Considering that the accelerated management system has 1.5 lactations per year, yearly lactation yield will be even higher. This experiment was designed as a cross-over experiment with the same group of ewes starting to lamb and lactate again in their second parity at the beginning of October 2019. Ewes previously enrolled in the HF group will receive the LF inclusion diet and vice versa. Further, feed chemistry as well as protein requirements for wool growth will be determined, analyzed, and put into context. Fatty acid composition of the milk will be illuminating in terms of mammary uptake of dietary, long-chain fatty acids and short-chain de novo fatty acid production within the mammary gland and potential effects of diet on milk fat composition.

Preliminarily we conclude that 1) crossbreeding with East Friesian dairy breed genetics may lead to extended lactation persistency compared with meat breed sheep; 2) the ability to conceive out-of-season is retained in these hybrid ewes; and 3) higher forage inclusion (< 200 g additional voluntary forage intake) leads to lower daily and lactation yields with no effect on milk components.

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